Cross-Function and Same-Function Alliances: How Does Alliance Structure Affect the Behavior of Partnering Firms?

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Firms collaborate to develop and deliver new products. These collaborations vary in terms of the similarity of the competencies that partnering firms bring to the alliance. In same-function alliances, partnering firms have similar competencies, whereas in cross-function alliances, partners have very different competencies. On examining managers' view of these alliances, we find that, on average, same-function alliances are expected to perform better than cross-function alliances, holding fixed the level of inputs. A game-theoretic analysis shows that this apprehension about cross-function alliances is consistent with a Pareto-inferior equilibrium. A Pareto-superior equilibrium, however, suggests that partners in cross-function alliances may invest more in their alliances than those in same-function alliances. It is also often believed that increasing the number of partnering firms is not conducive for collaborative effort. Our analysis shows that this belief is correct for same-function alliances, but not for cross-function alliances. We test these equilibrium predictions in an experiment where we exogenously vary the type of alliance and the number of partnering firms. The experimental results lend support for the Pareto-superior equilibrium. Partners in cross-function alliances invested more than their counterparts in same-function alliances, and this difference in investment levels increased with the number of partnering firms. We extend our model to consider alliances where firms have an opportunity to learn from their partners and later leverage this knowledge outside the scope of their alliance. Though such learning increases the resources committed by alliance partners in the learning phase, it decreases investment in the subsequent competition and also dampens the overall investment across the two stages. In addition, an increase in interalliance competition decreases investments in the focal alliance but increases investment in the competition outside the scope of the alliance.

Key words: alliance structure; experimental economics; game theory; new product development; organizational learning

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1. Introduction

Many firms rely on interfirm collaborations rather than internal processes to develop and market products. Such collaborations allow firms to gain access to complementary resources that they need for their survival and growth, combine similar resources possessed by the other firms to exploit new business opportunities, and learn new skills that can be leveraged outside the scope of the alliance. These potential advantages, however, can be negated, if partnering firms do not fully commit the needed resources for the alliance. Such an eventuality is quite possible, because these collaborations present numerous opportunities for firms to free ride on the investments of their partners. In addition, if a firm expects any of its partners to free ride, it might be appropriate for the firm to commit fewer of its own resources, again increasing the probability that the alliance fails.

1.1. Our Purpose

In this paper, we study three factors that might influence the resource commitment decisions of alliance partners: the nature of the resources each partner brings to the alliance, the number of partners in the alliance, and the opportunity to learn from partnering firms. Although alliances differ substantially in the degree to which the partnering firms possess similar or complementary resources (Hennart 1988) and in the number of partners within an alliance, little is known from prior research on how these organizational design factors might influence the amount of resources committed by partnering firms (Williamson 1983, Dussauge et al. 2000). Instead, prior studies have focused their attention primarily on the connection between the conditions surrounding alliance formation and the stability of alliances (Beamish 1985, Bucklin and Sengupta 1993, Gomes-Casseres 1994,

Robertson and Gatignon 1998, Branstetter and Sakakibara 2002). Similarly, although a growing body of literature studies the learning processes that take place within alliances (e.g., Hamel 1991, Dodgson 1993, Mowery et al. 1996, Dussauge et al. 2000, Inkpen 2000, Rindfleisch and Moorman 2001), few investigate how learning might influence the resources committed by partnering firms (e.g., Khanna 1998, Khanna et al. 1998).

To appreciate how collaborations vary in the similarity (dissimilarity) of the resources pooled by partnering firms, consider the alliance formed by IBM, Sony, and Toshiba to develop high-performance, low-power chips for consumer electronics. To make this alliance a success, IBM contributed its knowledge of chip technology, Sony its expertise in consumer electronics, and Toshiba its manufacturing expertise (Thomson Reuters Database 2002a). We also see biotechnology firms forging alliances with large pharmaceutical firms to market their innovative drugs. These collaborations are examples of alliances that link partners with diverse sets of resources, and are referred to as *cross-function or link alliances* (Mitchell et al. 2002). In contrast, Advanced Micro Devices (AMD) and Fujitsu have pooled their expertise in flash memory chips to jointly produce such chips (Thomson Reuters Database 2002b). Similarly, many firms engage in collaborative research and development (R&D) to help increase the scale of their innovation. In these alliances, partners pool similar resources, and they are commonly referred to as *same-function or scale alliances*.¹

Because partners in a cross-function alliance are often specialists, they are more interdependent. That is, firms in a cross-function alliance cannot easily compensate for the efforts of their collaborators, if their partners fail to commit the necessary resources. This vulnerability might lead partners in a cross-function alliance to commit fewer resources to the joint endeavor. Another factor that might affect the resource commitment decisions of alliance partners is the number of partners in an alliance (Gulati 1998). We note that most alliances are composed of only two partners. However, Li et al. (2009) report that approximately 10% of the firms listed in the Thomson alliance database are composed of three or more partners. An example of a multipartner alliance is the 11-partner alliance formed to develop advanced system-on-chips. This 11-partner alliance includes NEC, Matsushita, OKI, Rohm, and Sharp,

among others. Another multiparty alliance example is the IBM-Sony-Toshiba alliance discussed earlier. It is believed the uncertainty about the likely behavior of alliance partners increases with the number of partners. This strategic uncertainty might impact the resources committed by partnering firms, and thus the ultimate outcome of the alliance. Consequently, larger alliances may fail more often. Yet, in some instances alliances with more partners fail less often (e.g., Park and Russo 1996).

Finally, note that alliances not only allow firms to gain access to the resources of partnering firms, but also provide opportunities to learn from partners and leverage the new knowledge beyond the scope of their alliance (see Dussauge et al. 2004 for a review). These learning opportunities could motivate partnering firms to commit more resources to their alliance. However, the prospect of partnering firms subsequently using this knowledge against the focal firm may impede investments in the collaboration. There is a need to understand how these two opposing forces influence the overall investment in cross-function and same-function alliances.

1.2. Overview

Our research attempts to answer three related questions: First, what is the prevailing view about the performance of same-function and cross-function alliances for a given level of input from each partnering firm? Second, how do these perceptions affect the strategic investment behavior of alliance partners? Third, how does the potential for learning influence the investment behavior of partners in an alliance?

Building on the pioneering work of Steiner (1972) on group performance and that of Einhorn (1971) on decision making, we specify a mapping of the individual partners' resource allocations into an overall alliance performance measure for both types of alliances. We then conduct three surveys. In the first two surveys, we show that our specifications are compatible with the prevailing view about the performances of these two types of alliances, conditional on given levels of input from each of the partners. These studies also suggest that in instances where at least one partner shirks, cross-function alliances are perceived to have *lower* levels of performance than same-function alliances, with all else equal. In the third survey, we find, consistent with our specifications, that firms in cross-function alliances are naturally predisposed to contribute more if they expect the partnering firms to invest more, but contribute less if they expect their partners to invest less. But partners in same-function alliances tend to make up for the underinvestment by their partners, and such a behavior reduces the correlation in the investments of the partnering firms.

¹ This typology of alliances is consistent with Park and Russo's (1996) distinction between *integrative* and *sequential* alliances. It also reflects the spirit of Porter and Fuller's (1986) *X-form* and *Y-form* coalitions. In *X-form* coalitions, partners divide the activities in the value chain, whereas in the *Y-form* coalitions they jointly perform the same activity in the value chain.

Based in part on the results of our three surveys and in part on the extant literature, we next develop a model of competing alliances. In this model, we consider same-function and cross-function alliances by varying how the inputs of partnering firms influence the performance of an alliance. Furthermore, we assume that the resource allocation decision is *endogenous* and that firms are strategic when making their investment decisions. We use a game-theoretic analysis to determine how the magnitude of the collective investments of alliance partners is influenced by the type of alliance and the number of partners in the alliance.² Consistent with the common fear of alliance managers, we find an equilibrium where partners in a cross-function alliance will not invest in their alliance and also earn nothing. But in another equilibrium, which is Pareto-superior, partners in cross-function alliances make positive contributions to their alliance, and in this case they invest more than their counterparts in a same-function alliance. This difference in the collective investments becomes larger as the number of partners in an alliance increases.

Next we attempt to empirically establish a causal relationship between alliance structure and the investment behavior of partnering firms. To do this, we design a study where we observe different alliance structures as well as the investments of partners in these alliances, while controlling for other explanatory variables. Because conducting such a study in a field setting is extremely difficult, we instead use the tools of experimental economics to set up a competitive industry where we exogenously assign firms (participating managers) to a particular alliance structure and then measure the investments of each of the partnering firms. Using this approach, we validate two key predictions of our model. In particular, we examine how alliance type (same-function versus cross-function) and number of partners ($n = 2$ versus $n = 4$) affect the joint investment in an alliance. The experimental results show that partners in cross-function alliances play the Pareto-superior equilibrium. Hence, the observed joint investments in cross-function alliances are more than those in same-function alliances. Furthermore, the difference in joint investments grows as the number of partnering firms increase.

We then extend our base model in two important ways. First, we consider alliances where partnering

firms can acquire new knowledge from the collaboration and use it competitively outside the scope of the alliance. Our analysis of such a learning alliance shows that as the opportunity for learning increases, alliance partners will invest more resources in the focal collaboration, but reduce their investments in the subsequent competition outside the scope of the alliance. Interestingly, the total investment across the two phases also decreases as the opportunity for learning increases. We observe the same pattern of results in both same-function and cross-function alliances. Second, we explore what might happen if there exists inherent inefficiencies in pooling dissimilar resources in cross-function alliances. Here we show that in such cases partners might strategically invest less than their counterparts in same-function alliances.

In the next section, we describe our attempt to understand managers' prevailing view on how a partner's inputs affect the performance of same-function and cross-function alliances. In §3, we use this mapping of inputs onto performance to develop a model of interalliance competition and examine its implications. Section 4 presents and discusses a laboratory test of the model. In §5, we extend our basic model of interalliance competition to allow for learning and inefficiencies. Section 6 summarizes the major findings and concludes by briefly discussing directions for further research.

2. Prevailing View on Cross-Function and Same-Function Alliances

2.1. Pooling of Resources

The goal of this section is to investigate managers' prevailing view on how the inputs of partnering firms are combined to determine the output of an alliance. To facilitate exposition, we focus on pure same-function and pure cross-function alliances in this basic model.

This exploration is based on the psychology literature concerning both group performance and decision making (see Kerr and Tindale 2004). Steiner (1972) suggests that the performance of a group is related to the resources pooled by its members. Some tasks require all the members to contribute similar resources. An example of such a task is a "tug of war," where a group of individuals jointly pull a rope. In such a task, one member can potentially compensate for the lack of effort of another member of the group. He refers to such a group task as an additive task and models the performance of the group as the sum of the inputs of individual members. We see similarity between the performance of an additive group task and the performance of a same-function alliance: The inputs of partners are compensatory in nature, and

² We make no assumption about the governance structure for these alliances. Thus, the alliances could involve equity ownership and shared managerial control or the creation of a new organization (e.g., GM-Suzuki joint venture), or could involve no equity arrangements, with each partner in the alliance earning profit from selling its part of the technology platform (e.g., Wintel). Our only assumption is that these independent profit-maximizing firms are linked together by a common platform or shared purpose.

the joint performance can be captured by an additive function. Hence, we model the output (performance) of a same-function alliance i as $P_s(i) = f_s(\sum_{j=1}^{n_i} x_{ij})$, where x_{ij} is the input of partner j in alliance i , and n_i is the number of partners in the alliance.

Steiner (1972) notes that in group tasks where there is specialization or division of labor, the group's performance depends on the willingness of every member to perform his or her function properly. For example, the task of building a house requires inputs from plumbers, electricians, and carpenters. If the plumbers go on strike, it would be hard, if not impossible, for the electricians and carpenters to complete the overall task. Steiner (1972) refers to such a group task as a conjunctive task. We observe strong similarities between the performance of conjunctive group tasks and the performance of cross-function alliances. Thus, as in the conjunctive group task, the performance of a cross-function alliance depends on each partner properly performing her own unique subtasks, because no partner is able to pick up the slack if one of the other partners shirks. That is, it is often difficult or impossible for a firm to increase its scope such that it can compensate for the efforts of another partner in a cross-function alliance. Hence, in alliances where partners pool complementary resources, it takes only one aberrant partner to spell failure for the joint endeavor. To model this interdependence we follow the lead of Einhorn (1971), who showed that when the inputs are complementary (i.e., the task is conjunctive), the output is well represented with a multiplicative function. This leads us to model the performance of cross-function alliance i as $P_c(i) = f_c(\prod_{j=1}^{n_i} x_{ij})$, where n_i is the number of firms in alliance i . In this formulation, if one partner shirks, the efforts of other firms will not be as effective, and this decrease in effectiveness increases with the degree to which the individual partner shirks. It is an empirical question whether these simple formulations reflect the prevailing view on how same-function and cross-function alliances perform. We next test the robustness of our formulation by asking participants with managerial experience to state their views about an alliance's performance based on (a) the type of alliance and (b) the degree to which each partner contributes its share of resources.³ We first describe the experiment and then present our analyses of how well our model captures the prevailing view of managers.

³ We study the prevailing view about the performance function and not the actual performance function, because managers base their decisions on this view or belief. However, we later assume that manager's views about the performance functions are unbiased estimates of the actual performance functions.

2.2. Method

We start our exploration with a within-participant experiment using a sample of 70 MBA students. These students had, on average, 5.4 years of work experience. They were paid a flat fee of \$7 for taking part in the study.

A questionnaire was administered to each participant individually in the laboratory. The questionnaire described two scenarios in which two firms come together to develop a new fuel cell car. In one scenario, designed to represent a same-function alliance, both the partners were car manufacturers who shared some of their R&D expertise to jointly develop the new car. In the other scenario, designed to represent a cross-function alliance, one partner was an engineering firm with expertise in fuel cell technology, and the other partner was a car manufacturer with core capabilities in production and marketing. In neither case were the terms same- or cross-function used while describing the alliance to the participants. However, as we soon show, each scenario was correctly perceived to describe the characteristics associated with appropriate alliance. For a description of the survey measurement instrument, see the online technical appendix (provided in the e-companion).⁴

After participants read one of the alliance scenarios, they were told that if both partners in the alliance were to contribute 100% effort, then the likely performance of the alliance would be 100%. Anchoring on this 100% performance benchmark, participants were asked to rate the likely performance of an alliance for 24 other combinations of inputs, where at least one partner's input was less than 100% effort. After completing this task, the participants read the second alliance scenario. Then for the very same set of input configurations, they rated the likely performance of the second alliance. The order of presentation of the two alliance scenarios was rotated between participants so that the description corresponding to the same-function (or cross-function) alliance was equally likely to appear in the first and second positions.

2.3. Manipulation Check

Using a different sample of 60 participants drawn from the same population, we verified the degree to which the two scenarios described in our survey instrument were perceived to represent a same-function and a cross-function alliance. After reading the description of the two alliance scenarios, the participants were asked to indicate on a seven-point scale the extent to which they agreed with the following statements: "Partners in the alliances pooled very similar resources," "If my partner in the alliance does

⁴ An electronic companion to this paper is available as part of the online version that can be found at <http://mansci.journal.informs.org/>.

not put in enough effort, I can make up for it by putting in more effort,” and “The partners are very much dependent on each other.”⁵ The responses to these three statements were highly correlated, so we averaged them (after reverse coding the third statement) to form one index (Cronbach’s $\alpha = 0.91$). We then compared this three-item index across the two scenarios. The mean score for the same-function alliance scenario was 2.84, whereas the corresponding score for the cross-function alliance scenario was 6.33 ($t = 24$, $p < 0.001$). We take this as strong evidence that participants saw these two alliance scenarios as possessing different characteristics.

2.4. Tests of Performance Model

In developing our theoretical model, we assume that the performance of a same-function alliance is a function of the sum of the individual inputs. That is, $P_s = \beta_1 \sum_{j=1}^{n_i} x_{ij}$, where β_1 is a scaling constant that translates the inputs onto the performance scale. Similarly, we assume the performance of a cross-function alliance is given by $P_c = \beta_2 \prod_{j=1}^{n_i} x_{ij}$.

This simple formulation has some interesting implications. First, we should observe more variance in the perceived performance of cross-function alliances compared to the performance of same-function alliances, where the variance is taken across all the different input levels. This is because the variance of a product of variables is larger than the corresponding variance of the sum of those variables. Next, note that in our survey instrument we specified that $P_s = P_c = 100$ when both partnering firms put in 100% effort. This implies that, in theory, $\beta_1 = 0.5$ and $\beta_2 = 0.01$, and thus the ratio $\beta_1/\beta_2 = 50$. Also, if the participants use the appropriate scaling factors while combining the inputs to predict the performance of the same-function and the cross-function alliances, the mean predicted performance of the same-function alliance across the 25 different scenarios should be higher than that of the cross-function alliance. We next test for all three of these implications.

2.5. Results

The average within-person variance in the predicted performance of cross-function alliances is 454, whereas the corresponding variance in the performance of same-function alliances is 313. We can reject the null hypothesis that these average variances are the same ($p < 0.065$).

⁵ Thirty participants rated the same-function alliance scenario first, and then the cross-function alliance scenario. The other 30 participants rated the two scenarios in the reverse order. Because there was no order effect, we pooled the data. In the seven-point scale, 1 = strongly agree, whereas 7 = strongly disagree.

When we compare the mean within-person predicted performances of the two types of alliances, we find participants, on average, rated the same-function alliance to perform better than the cross-function alliance. Across the 70 participants, the average likely performance for our sample of 25 same-function alliances is 63.68%. The corresponding average performance of the cross-function alliances is 57.20%. We can reject the null hypothesis that the mean performances of the two types of alliances are the same ($t = 14$, $p < 0.001$).

Finally, we explore the size of the ratio β_1/β_2 . Because we want to remove individual-level systematic biases in the ratings of these alliances, we examine the difference in the performances of the two types of alliances for the same set of inputs. Specifically, the difference in the performance of a same-function alliance (P_s) and a cross-function alliance (P_c) for a given set of inputs is

$$\Delta P = P_s - P_c = \beta_1 \sum_{j=1}^{n_i} x_{ij} - \beta_2 \prod_{j=1}^{n_i} x_{ij}. \quad (1)$$

As predicted, the mean estimates of β_1 and β_2 of the random-coefficients model are significant ($\beta_1 = 0.1061$, $t = 4.81$, $p < 0.0001$; $\beta_2 = 0.00212$, $t = 4.20$, $p < 0.0001$). More importantly, the size of the ratio $\beta_1/\beta_2 = 50.47$ is very close to the predicted value of 50.

2.6. Discussion

In sum, the results of this survey show that the proposed performance formulations for same-function and cross-function alliances reflect the essence of our participants’ view about the performances of these two types of alliances. In addition, as predicted by our formulation, the perceived performances of same-function alliances have a higher mean and lower variance, holding fixed the inputs of alliance partners. Note, however, that the description of alliances provided to respondents of Survey 1 did not specifically rule out opportunities for a firm to learn from its partners. Because this raises the possibility that the response of our participants might have been based on perceived opportunities for learning, we address this issue in Survey 2.

2.6.1. Survey 2. In this survey, we use the same stimuli and procedure as in Survey 1, but clarify that firms have no opportunity to learn from alliance partners. Furthermore, we ask our respondents to rate the performance of an alliance where one partner contributed nothing and the other contributed 100%. We added this specific combination of inputs to the stimuli because it will evoke a very stark contrast between the perceived performance of a same-function alliance and that of a cross-function alliance. We surveyed

40 respondents for this survey, and the survey instrument can be seen in the online technical appendix.

On analyzing the response, we find that the average likely performance of same-function alliances is 64.45%, whereas that of cross-function alliances is 55.44%. We can again reject the hypothesis that these two levels of performance are the same ($t = 14.04$, $p < 0.001$). However, we cannot reject the hypothesis that the mean likely performances observed in Surveys 1 and 2 are statistically different from each other for either alliance type (same function, $t = 0.037$, $p > 0.9$; cross-function, $t = 0.072$, $p > 0.9$). Thus, ruling out any possibility for learning does not seem to affect the mean responses of our participants.

We also estimate Equation (1), again using a random-coefficients model. We find that the mean estimates of β_1 and β_2 are significant ($\beta_1 = 0.1539$, $t = 5.39$, $p < 0.0001$; $\beta_2 = 0.0033$, $t = 5.73$, $p < 0.0001$). Furthermore, the size of the ratio $\beta_1/\beta_2 = 46.64$, which again is close to the predicted value of 50.

In the special case where one partnering firm contributed no effort and the other contributed 100% effort, the average perceived performance of same-function alliances is 38.13%, whereas that of cross-function alliances is 5.95%. Furthermore, 62% of our respondents predicted that the performance of the cross-function will be 0% for this given combination of inputs. Thus, our respondents recognize that when one partner fails to contribute, it impairs the performance of a cross-function alliance far more than a same-function alliance.

In both Surveys 1 and 2, we compared the *performance* of the two types of alliances for an exogenously given set of inputs by the two partnering firms in an alliance. This leads to the next question, how much *effort* will a firm contribute to the two types of alliances for an exogenously given input by the partnering firm? We address this question in Survey 3.

2.6.2. Survey 3. In this survey, we ask 40 respondents to indicate how much effort they will commit to a cross-function alliance as well as a same-function alliance for 15 different levels of inputs by the partnering firm. Note that we do not inform respondents about how the inputs of alliance partners determine the joint performance of either a same-function or a cross-function alliance. Hence, the respondents need to integrate their naturally formed views about the performance of the two types of alliances with the information available about the level of input from the partnering firm, and then decide on how much effort to contribute to the collaboration. Thus, this survey helps us to directly examine how a partnering firm's resource input affects the focal firm's resource commitment.

To focus our discussion of the results of Survey 3, consider the following regression model:

$$x_{1lk} = \beta_0 + \beta_1 \text{Type} + \beta_2 x_{2l} + \beta_3 (\text{Type} * x_{2l}), \quad (2)$$

where x_{1lk} is the percentage of effort contributed by respondent k for the exogenously given effort level x_{2l} by its partnering firm. The subscript l indexes the 15 different effort levels of the partner, and *Type* is a binary variable with zero indicating cross-function alliance and one indicating a same-function alliance. On estimating the random-coefficients model in Equation (2), we find that the mean estimate of β_2 is significant, suggesting that firms are likely to reciprocate the effort contributed by their partner though not fully ($\beta_2 = 0.707$, $t = 27.28$, $p < 0.001$). Perhaps more interestingly, the mean estimate of β_1 is significant, implying that, on average, firms are predisposed to contribute more to a same-function alliance ($\beta_1 = 22.46$, $t = 2.79$, $p < 0.01$). However, this tendency decreases as the partnering firm puts in more effort, as can be seen in the mean negative value of β_3 ($\beta_3 = -0.292$, $t = 3.17$, $p < 0.005$). Thus, on average, our respondents committed more effort in a cross-function alliance than in a same-function alliance when their partner invested at least 76.98%, but otherwise contributed less effort when their partner invested less. We also find the correlation between each respondent's effort and their partner's contributions is 0.46 ($p < 0.001$) in same-function alliances but 0.741 ($p < 0.001$) in cross-function alliances. These findings are compatible with the premise that managers perceive the performance of a cross-function alliance in terms of a multiplicative function. Consequently, we should expect more extreme tit-for-tat behavior in cross-function versus same-function alliances.

In summary, all three surveys support the conjecture that the performance of cross-function alliances is well captured by a multiplicative function, whereas that of same-function alliances can be modeled using an additive function. In Surveys 1 and 2, we compared the performance of the two types of alliances for an *exogenously* given set of inputs of both partnering firms, whereas in Survey 3, we looked at the initial investment resource decision of the focal firm assuming an *exogenously* given level of input by the partnering firm. In real-world alliances, however, each partnering firm *endogenously* decides on its input level based on the type of alliance. This raises the following question: If firms behave *strategically*, would partners in a cross-function alliance invest more or less than those in a same-function alliance when effort is endogenous? Next we examine this question both theoretically and empirically.

3. Theoretical Analysis

Our goal in this section is to capture how our two key constructs impact each partner's resource allocation decision and, consequently, the success of the alliance. This requires us to specify what we mean by a partner's investment and how these investments translate into possible success. We assume that all of the investments made in an alliance are nontransferable. In other words, the investments have no value if the joint endeavor fails. This assumption about the investments' value is very similar to Williamson's (1983) concept of asset specificity, where the asset only has value for a specific application (see also Bensaou and Anderson 1999, Wathne and Heide 2000). In our initial theoretical analysis, we assume that there is no leakage of a firm's knowledge to its partners and that there is no inefficiency in combining dissimilar resources. We later extend our base model to consider both of these factors.⁶

Based in part on our survey findings and in part on the conceptual work of Steiner (1972) and Einhorn (1971), we define a same-function alliance to be one where the ultimate value of the alliance output is an additive function of the inputs of the partnering firms, whereas in a cross-function alliance the value of the alliance is a multiplicative function of the investments of partnering firms. We define the likelihood of success of an alliance in terms of its output value relative to the sum of all output values associated with the investments of all the competing alliances. Thus, as the total investment in an alliance increases, the probability of the alliance's success raises, all else equal. This probability of success, however, decreases with the investments of competing alliances. Moreover, by letting the outcome be a probabilistic function, our model reflects some of the uncontrollable market and technological vagaries faced by alliance partners. Finally, we assume each partner is strategic when making its investment decision, and in doing so considers the actions of its partners and competitors. We quantify these assumptions next.

3.1. A Model

Consider N alliances that are competitively developing a new product, and index them by $i = \{1, 2, \dots, N\}$. There are n partners in each alliance. Denote the investment of partner j in alliance i by x_{ij} ($0 \leq x_{ij} \leq z_{ij}$), where z_{ij} is some upper bound on investments for partner j , and denote the collective investment in alliance i by $X_i = \sum_{j=1}^n x_{ij}$. We assume that the output of an alliance determines the performance (utility)

of its product. Then the performance of the product developed by same-function alliance i is

$$U(i) = \beta_1 \sum_{j=1}^n x_{ij}, \quad (3)$$

where β_1 is a scaling constant, whereas the performance of a product developed by a cross-function alliance i is

$$U(i) = \beta_2 \prod_{j=1}^n x_{ij}, \quad (4)$$

where β_2 is another scaling constant.

We capture the impact of both the absolute and relative investments by assuming the probability of alliance i winning the competition, $\Pr(i)$, is⁷

$$\Pr(i) = \frac{U(i)}{\sum_{k=1}^N U(k)}. \quad (5)$$

We also assume that alliance partners make their investment decisions simultaneously so that they cannot condition their behavior on the decisions of either their partners or their competitors. Thus, our model reflects the uncertainties resulting from difficulties in monitoring the behavior of alliance partners and competitors. In this one-period game, firm j in alliance i maximizes its expected payoff:

$$\pi_{ij} = -x_{ij} + \Pr(i) \frac{V}{n}, \quad (6)$$

where V is the exogenously determined gross profits associated with successfully winning the interalliance competition. Thus, the interalliance competition is modeled as a noncooperative game, where the values of n , N , V , and the performance formulation are commonly known. We solve for the symmetric Nash equilibrium of this game and study its implications. Our analysis assumes that players think through the implications of investing different amounts of resources, and then they simultaneously settle on the optimal level of investment. The proofs can be seen in the appendix.

3.2. Effect of Type of Alliance

The interdependence among partners in a cross-function alliance raises an interesting practical issue: Even if only one partner in a cross-function alliance invests nothing, the utility of the product jointly

⁶ We have also considered the case where alliance partners pool some similar resources and some complementary resources. The results of this analysis are available from the authors.

⁷ In general, there are three broad classes of the process by which the winner could be determined: auctions (e.g., Dasgupta and Stiglitz 1980), stochastic racing (e.g., Lee and Wilde 1980), and contest models (e.g., Tullock 1967). The auction models are deterministic and focus only on strategic uncertainty. The stochastic racing models and contest models allow for both outcome and strategic uncertainty. Our formulation is most similar to the contest model.

developed by the alliance will be reduced to nothing. Consequently, there is reason for managers to be apprehensive about the performance of cross-function alliances, and this apprehension is reflected in our survey results. On analyzing competition between alliances, it is easy to see that investing nothing in a cross-function alliance is *one* possible Nash equilibrium. Thus, our analysis provides a game-theoretic rationale for an important apprehension discerned in our survey and reflected in the folk wisdom about cross-function alliances.

Although this interdependence can have a chilling effect on investment, note that the marginal benefit of investing in a cross-function alliance is augmented by the investments of other partners. Hence, this interdependence may motivate players to invest more in the joint endeavor. Consistent with this view, there is a *Pareto-superior* equilibrium where each partner invests a positive amount in the cross-function alliance. More interestingly, in this Pareto-superior equilibrium, the joint investment in a cross-function is greater than that in a same-function alliance. More formally, we have the following proposition:

PROPOSITION 1. *In the Pareto-superior equilibrium, collective investment in a cross-function alliance will be more than the collective investment in a same-function alliance, all else equal.*

It is of course an empirical question whether or not partners in a cross-function alliance play this Pareto-superior equilibrium and thereby invest more than those in a same-function alliance. If alliance partners are apprehensive of their partners, they could well invest nothing and thereby choose the Pareto-inferior equilibrium. We later test the descriptive validity of Proposition 1. Here after, while discussing the joint investment in cross-function alliances, we focus on the Pareto-superior equilibrium.

3.3. Effect of Number of Partners

It is commonly viewed that increasing the number of partners in an alliance dampens the total investment associated with the alliance because of potential free-riding behavior. We find that the equilibrium collective investment of partners in same-function alliance i is a *decreasing* function of the number of partners in the alliance ($\partial X_i / \partial n_i < 0$). On the other hand, the collective investment of cross-function alliance i is *independent* of n ($\partial X_i / \partial n_i = 0$). This result is true whether the equilibrium outcome is a Pareto-superior or Pareto-inferior. Hence, we have the following:

PROPOSITION 2. *In same-function alliances, the collective investment of partners decreases as the number of partners within an alliance increases. But in cross-function alliances, the collective investment made by an alliance does not depend on the number of partnering firms.*

3.4. Discussion

Our analysis offers a potential strategic rationale for why cross-function alliances are perceived to perform worse than same-function alliances, all else held equal. Investing nothing in a cross-function alliance is indeed a Pareto-inferior equilibrium of the inter-alliance competition game. The Pareto-superior equilibrium, however, shows that strategic behavior leads each partner to invest in a cross-function alliance, and this investment is larger than the investment from a same-function alliance. Furthermore, the relative decrease in collective investment in a same-function alliance compared to that in a cross-function alliance is more pronounced when the number of partnering firms increases. We next assess the empirical accuracy of some of the predictions of this model.

4. Empirical Investigation

We acknowledge that managers probably do not solve for equilibrium behavior using our game-theoretic analysis before making their investment decisions. Instead, we conjecture that their decisions are guided by some simple heuristics. The question then is as follows: If the market is defined by Equations (2)–(5), will managers behave, at least in the aggregate, *as if* they are rational profit maximizers? The answer will be negative if managers are apprehensive of any free-riding behavior from their partners, because the natural response based on such a belief is to commit fewer resources for the joint endeavor than implied by our model. Such a tendency to underinvest has been observed in the presence of strategic complementarity between the actions of individual players (e.g., Weber 2001; Cooper et al. 1990; Van Huyck et al. 1990, 1991). Moreover, the tendency to underinvest may become more acute as the number of partnering firms increases, because there is more opportunity for shirking. Thus, it is an empirical question whether or not partners in a cross-function alliance will conform to the Pareto-superior equilibrium.

Our experiments are designed to test Propositions 1 and 2. Specifically, we are interested in understanding how the type of an alliance and the number of partnering firms influence the investment decisions of financially motivated agents. In the tradition of experimental economics literature, we allow individual participants to represent a firm (see Smith 1989, Holt 1995, Amaldoss et al. 2000, Weber and Camerer 2003, Amaldoss and Rapoport 2005, Ho and Zhang 2008).

4.1. Experimental Design

We conduct a 2×2 between-participants factorial design with two types of alliances (additive or conjunctive task) and two levels of alliance size ($n = 2$ or 4). We conduct two replications of each treatment.

Sixteen participants participated in each session for a total of $16 \times 4 \times 2 = 128$ participants. Participants were recruited from the same pool of MBA managers used in our surveys by promising a monetary reward contingent on their performance in a decision-making experiment in addition to a show-up fee of \$5.

4.2. Procedure

The participants were randomly seated in 16 computer booths so that there was no face-to-face interaction among participants. After reading the instructions for the experiment, the participants played five practice trials to familiarize themselves with the task. If participants had any questions during these practice trials, they were answered.

On each trial, the 16 participants in the session were randomly divided into either eight or four alliances of either two or four participants, that is, $n \in \{2, 4\}$. The number of partners in an alliance size varied across experimental sessions, but remained unchanged within a session. The assignment schedule ensured that each participant was randomly aligned with a different set of participants and competed against another randomly selected alliance on each trial. Hence, the participants had no way of knowing the identity of their partners or their competitor alliance on any given trial. Therefore, reputation effects were minimized and each trial can be thought of as a one-period game.

At the commencement of the session, each participant was informed of the number of partners in an alliance, that is, $n = 2$ or $n = 4$. Participants also were told how the resources of the partnering firms were pooled to determine the performance (utility) of the jointly developed product, namely, whether the utility formulation was an additive or multiplicative function. Both the number of partnering firms and the utility formulation remained unchanged throughout the session. All transactions were in an experimental currency called “francs.” In all experimental conditions, each trial began with each participant being endowed with 24 francs, an amount that exceeded the optimal equilibrium investment. The market size (that is, the value of winning the interalliance competition) remained fixed throughout the experiment at $V = 160$ francs.

Each participant had to decide how much capital to invest in the product that was to be jointly developed by his/her alliance. Participants could invest any amount, including zero, provided the investment did not exceed the endowed capital, that is, $0 \leq x_{ij} \leq 24$. After all the participants made their investments privately and anonymously, the computer assessed the collective investments made by the competing alliances. The winning alliance was determined probabilistically according to Equation (4). Participants in the winning alliance received an equal

share of the market plus the difference between their endowed capital and their investment. Participants in the losing alliance received only the difference between their endowed capital and their investment. If all alliances invested nothing, then no alliance won the competition. At the end of each trial, participants were informed of the total investments made by the winning and losing alliances, the probability of their alliance winning the competition, the winning alliance, their personal payoff for the trial, and their personal cumulative payoff.

The participants were provided with paper and pencils to help them record the outcomes of past decisions if they wished to do so. This one-period game was replicated 120 times. At the end of the experiment, participants were paid according to their cumulative earnings over the several trials of the experiment, debriefed, and dismissed. Each session lasted between 90 and 120 minutes.

4.3. Results

Each of the 128 participants made 120 investment decisions. Using the resulting body of 15,360 investment decisions, we compare the investment behavior of alliance partners across the two different types of alliances and the two different sizes of alliances.⁸ We first examine how well, on average, the individual investments of the alliance partners follow the qualitative and the point predictions of the equilibrium solution. Then, we provide information on the variation of investment behavior across individuals.

4.4. Mean Investment of Individual Partner

Table 1 presents the mean individual investment made in a particular type and size of alliance averaged across participants in that treatment, along with the corresponding equilibrium prediction. In the case of cross-function alliances, we focus on the Pareto-superior equilibrium. The mean collective investments appear in parentheses.

4.4.1. Qualitative Predictions. The equilibrium solution implies two qualitative predictions for the individual level investments. First, as the number of partnering firms increases, individual investments should decrease. Second, assuming participants reach the Pareto-superior equilibrium, partners in cross-function alliance should invest more than their counterparts in same-function alliance holding the size of the alliance fixed. To test whether the experimental results support these predictions, we conduct

⁸ Because there was no significant difference between the two sessions in each treatment ($p > 0.1$), we used pooled data for subsequent analysis of variance. Also, consistent with current practice, we used decisions from all the 120 trials for our analysis. But as will be discussed later, there is a trend toward equilibrium behavior over the many iterations of this one-period game.

Table 1 Mean Investment of Individual Partners and Alliances
(by Type of Alliance and Number of Partners)

Type of alliance	Number of partners	Group	Investment	
			Actual investment	Equilibrium prediction
Cross-function	$n = 2$	Group 1	19.20 (38.40)	20 (40)
		Group 2	19.24 (38.48)	20 (40)
		Average	19.22 (38.44)	20 (40)
	$n = 4$	Group 1	11.60 (46.41)	10 (40)
		Group 2	11.86 (47.45)	10 (40)
		Average	11.73 (46.93)	10 (40)
	$n = 2$	Group 1	12.76 (25.52)	10 (20)
		Group 2	12.13 (24.26)	10 (20)
		Average	12.45 (24.88)	10 (20)
Same-function	$n = 4$	Group 1	4.73 (18.93)	2.5 (10)
		Group 2	5.32 (21.26)	2.5 (10)
		Average	5.025 (20.10)	2.5 (10)

Notes. The individual investment is the mean investment computed across the 16 participants in each cell. The collective investment of an alliance is indicated within parentheses. The table shows the Pareto-superior equilibrium prediction for cross-function alliances.

a two-way analysis of variance with two between-participant factors (*number of partners* and *type of alliance*), along with a control variable for session and all interaction terms.⁹ For this analysis, we use each participant's mean individual investment.

The two hypotheses are supported. In particular, as predicted by theory, the main effect of alliance type is highly significant ($F_{(1,120)} = 70.38$, $p < 0.0001$). Table 1 shows that the mean individual investment of partners in cross-function alliances is higher than those in same-function alliances. Also as predicted by theory, the main effect of number of partners was significant ($F_{(1,120)} = 86.05$, $p < 0.0001$), with participants investing less in larger alliances.

4.4.2. Point Predictions. Table 1 shows that the mean investments of individual participants in cross-function alliances are close to the point predictions of the Pareto-superior equilibrium as shown in the last

column. Across the two groups, participants in two-partner alliances invested, on average, 19.22 francs. The observed mean investment is not statistically different from the predicted 20 francs ($t = 1.13$, $p > 0.26$). Participants in cross-function alliances with four partners should invest 10 francs, and the observed mean investment is 11.73. In this case, the difference from the norm is significant ($p < 0.02$); partners in same-function alliances tended to invest more than the point predictions. On average, participants in alliances with two partners invested 12.45 francs, a figure significantly larger than the optimal value of 10 units ($t = 2.55$, $p < 0.02$).¹⁰ Participants in four-partner alliances invested, on average, 5.025 francs, which is significantly more than the model prediction of 2.5 ($p < 0.01$).

4.5. Mean Collective Investment of Alliances

Table 1 also reports within parentheses the mean collective investments of alliances. As predicted by Proposition 1, participants in cross-function alliances made larger collective investments compared to those in same-function alliances ($F_{(1,956)} = 4223.28$, $p < 0.0001$), holding the size of the alliance fixed. Proposition 2 predicts that the total collective investments should be affected by the number of partners in a same-function alliance, but not in a cross-function alliance. As predicted by our model, partners in same-function alliances invested less as the size of the alliance grew from two to four partners ($F_{(1,478)} = 127.05$, $p < 0.0001$). However, contrary to our theory, the average collective investments in cross-function alliances actually grew as their size increased ($F_{(1,478)} = 351.63$, $p < 0.0001$).

To detect potential trends in the collective investments, we divide the 120 trials into blocks of 10 trials and test for block effects. The block effects are significant, implying that participants might have modified their strategic investment behavior over the several iterations of the game, and in doing so more closely behaved in a fashion consistent with equilibrium predictions ($F_{(1,909)} = 13.58$, $p < 0.0001$). Figures 1 and 2 present the moving cumulative average of the collective investments over the 12 blocks of trials. In general, participants tended to overinvest in the initial blocks of trials, and then shifted toward the equilibrium predictions. However, in three of the four conditions, the mean investments seem to have stabilized above the predicted level.

4.6. Individual Differences

Although the above results are in line with our predictions, we note that all of them are based on investments aggregated over all of the individuals within

⁹ None of the interactions were significant, nor was the main effect for session.

¹⁰ Looking at the level of individual groups, we note that participants in Group 1 and Group 2 invested 12.76 and 12.13 francs, respectively (Group 1: $t = 1.72$, $p > 0.10$; Group 2: $t = 1.82$, $p > 0.08$).

Figure 1 Trends in Collective Investments ($n = 2$)

Note. The equilibrium prediction is 20 francs for same-function alliances with two partners, whereas the Pareto-superior equilibrium prediction is 40 francs for cross-function alliances.

Figure 2 Trends in Collective Investments ($n = 4$)

Note. The equilibrium prediction is 10 francs for same-function alliances with four partners, whereas the Pareto-superior equilibrium prediction is 40 francs for cross-function alliances.

a particular condition. When we look at the distribution of mean individual investments within a particular condition, we find significant variance in behavior, as shown in Figures 3 and 4. Thus, some individuals in each condition tended to overinvest in their alliances and others tended to underinvest. However, the majority of participants tended to overinvest, except in the two-partner cross-function alliance, where participants might have experienced some ceiling effect. Although this willingness of a majority of participants to spend more than the optimal amount might have encouraged a minority of individuals to take advantage of others' tendency to overinvest, we find none of the partners in cross-function alliances had a mean investment equal to zero. We take this as further evidence that the Pareto-superior equilibrium provides a better account of the behavior, even at the individual level.

In sum, the experimental investigation provides both qualitative and quantitative support for Propositions 1 and 2 and the assertion that the behavior of partners in cross-function alliance is better accounted by the Pareto-superior equilibrium. However, these

Figure 3 Distribution of Mean Investments of Participants ($n = 2$)

Notes. The equilibrium prediction is 10 francs for same-function alliances with two partners. The Pareto-superior equilibrium prediction is 20 francs for cross-function alliances with two partners. The graph plots the distribution of 32 participants in each treatment (across the two groups).

Figure 4 Distribution of Mean Investments of Participants ($n = 4$)

Notes. The equilibrium prediction is 2.5 francs for same-function alliances with four partners. The Pareto-superior equilibrium prediction is 10 francs for cross-function alliances with four partners. The graph plots the distribution of 32 participants in each treatment (across the two groups).

findings are not in keeping with prior experimental research on games with strategic complementarity, where players have failed to select the equilibrium that gives the highest payoff from the set of available equilibria (Weber et al. 2001; Van Huyck et al. 1990, 1991; also see Cooper et al. 1990). In these prior games, the joint effort of a team is determined by the minimum effort of individual players. Thus, as in our cross-function alliance, it takes only one player to crucially undermine the joint performance of a team. But, in contrast to our interalliance competition game, there is no competition between teams in these prior games. This leads us to conjecture that the competition between alliances may motivate players to invest more and attain the Pareto-superior equilibrium.

5. Model Extensions

In the theoretical and empirical analysis discussed in §§3 and 4, we assumed that there are no opportunities for firms to learn from their alliance partners. However, sometimes firms forge alliances so they can also learn from partnering firms. In these alliances, collaborators earn both private and common benefits,

where the common benefits flow from the joint output of the alliance, and the private benefits accrue from a firm's ability to leverage its new knowledge outside the scope of the focal alliance (see also Khanna 1998, Khanna et al. 1998). Because the partners who are cooperating within an alliance may turn into competitors outside the scope of the focal alliance, firms need to carefully balance the cooperative and competitive consequences of alliances (Hamel 1991). Consequently, we next extend our model to investigate how opportunities for learning within an alliance and the subsequent competition among the partners outside the scope of the focal alliance affect a firm's investment in the focal alliance.

Consider a simple case where several alliances are competitively developing a new technology, and partners in the winning alliance can leverage some of their interpartner learning in a subsequent market competition. We model the first stage, where alliances are competing to develop a new technology, along the lines discussed in §3 (see Equations (3)–(5)). We introduce the parameter $\alpha \in (0, 1)$ to represent the fraction of total gross profits that accrues as the common benefit from the collaboration. Thus, each partner in the alliance that wins the technology competition earns a direct payoff of $\alpha V/n$.

In the second stage of the game, each partner in the winning alliance advances to compete in a market outside the scope of the focal alliance. Winning the second-stage competition depends on the resources a firm invests in this stage as well its learning from its alliance partners. We assume that firm j 's learning from its partners in same-function alliance i is given by

$$L_{ij} = \frac{\gamma \sum_{m \neq j} x_{im}}{n-1},$$

where $\sum_{m \neq j} x_{im}/(n-1)$ is the mean investment of firm j 's partners in the alliance. The parameter $\gamma > 0$ is a measure of firm j 's opportunity to learn from its partners. The corresponding learning of firm j from cross-function alliance i is modeled as

$$L_{ij} = \gamma \left(\prod_{m \neq j} x_{im} \right)^{1/(n-1)},$$

where $(\prod_{m \neq j} x_{im})^{1/(n-1)}$ is the geometric mean of the investments of firm j 's partners in the alliance.

Let y_{ij} denote the additional resources that firm j in alliance i invests in the second stage. Now the probability of firm j winning the competition outside the scope of its alliance is given by

$$\Pr(j) = \frac{L_{ij} + y_{ij}}{\sum_{m=1}^n (L_{ij} + y_{im})}.$$

Note that this probability hinges on both the learning from the first stage and the investments made in the second stage. Furthermore, it reflects the inherent uncertainties in a market-based competition. The

gross profits from winning the second-stage competition are $(1 - \alpha)V$. The resulting expected profits of firm j in alliance i are as follows:

$$\pi_{ij} = -x_{ij} + \Pr(i) \left(\frac{\alpha V}{n} + \Pr(j)(1 - \alpha)V - y_{ij} \right).$$

Using this extended model, we next explore how interpartner learning (γ) and the number of competing alliances (N) affect (a) the investments in the alliance (first stage), (b) the investment outside the scope of the alliance (second stage), and (c) the overall investment (across the two stages). We relegate the proofs to the online technical appendix.

PROPOSITION 3. (a) *As the opportunity to learn increases (i.e., the size of γ increases), the collective investment in same-function alliances increases. In the Pareto-superior equilibrium, the collective investment in cross-function alliances also increase with γ . However, an increase in γ reduces the investments in the competition outside the scope of the focal alliance and also the total investments.*

(b) *In situations where $\gamma > 0$, when the number of competing alliances increases beyond two, it decreases the joint investment in both types of alliances, but increases investment in the competition outside the scope of the alliances. The effect on overall investment is positive only if the learning opportunities are sufficiently high such that $\gamma > 1$.*

The intuition for the first part of Proposition 3 is that as learning opportunities improve, the benefits of collaboration increase because now a firm can use the increased learning outside the scope of the focal alliance. Consequently, partners in both same-function and cross-function alliances invest more in their joint endeavor. Interestingly this upfront "investment" decreases a firm's need to make additional investment in the competition outside the scope of its alliance, that is, $\partial y_{ij}/(\partial U(i)) < 0$. This is true irrespective of whether the firm is engaged in a same-function or a cross-function alliance. On balance, the effect of learning on the total investments across the two phases decreases with the size of γ .

The intuition for the second part of the proposition is almost the converse of the above logic. Now as N increases, it increases interalliance competition and reduces the expected value of winning the competition, and hence reduces the joint investment in a collaboration. But, as noted earlier, $\partial y_{ij}/(\partial U(i)) < 0$. Thus, as the increased interalliance competition decreases investments in the focal alliance, we observe an increase in the investments outside the scope of the alliance. This second-stage investment can increase the total investments across the two phases when the opportunities for learning are so high that $\gamma > 1$. Note that when $0 < \gamma \leq 1$, the returns from inter-partner learning are not high enough to increase the first-stage

investment such that it can more than compensate for the reduction in investment in the second stage of the game.

In this extended model, if $\alpha = 1$, a firm gains nothing by competing outside the scope of the alliance. Consequently, the model reduces to our original framework, and thus we can recover Propositions 1 and 2. We prove this claim in the appendix. So situations where $0 < \alpha < 1$ help us understand how learning modifies our basic findings. We find that as the size of α increases, it increases the joint investment in both same-function and cross-function alliances, but decreases the investment in the competition outside the scope of the alliance and also the total investment across the two stages unless $\gamma > 1$. It is useful to note that even in the presence of learning opportunities, the joint investment in a cross-function alliance is more than that in a same-function alliance. We also prove this claim in the appendix.

Finally, we look to see how robust the basic model findings are to the assumption that partners in a cross-function alliance can pool their resources as efficiently as those in a same-function alliance. In the management literature, it is normally assumed that partners have a greater absorptive capacity to learn new capabilities if they already have a competence base that is similar to this new capability (Cohen and Levinthal 1990). Moreover, partners pooling similar resources share more similar concerns, face more similar problems, and have less trouble coordinating their efforts. We model this difference in the effectiveness of the resources committed by partner j in alliance i by x_{ij}^δ , where $0 < \delta \leq 1$ for cross-function alliances and $\delta = 1$ for same-function alliances. We show in the appendix that, as the inefficiencies in a cross-function alliance increase, partners in cross-function alliances invest less. When $\delta < 1/n$, partners in same-function alliances will invest more than those in cross-function alliances. These results provide another plausible explanation for why in some circumstances, partners in cross-function alliances might be less committed to their joint endeavor. It also highlights the need for firms that enter into cross-function alliances to develop the necessary managerial expertise to efficiently pool their resources. There is some indication that firms are able to acquire such expertise over time by virtue of participating in a number of alliances (Li et al. 2009).

6. Conclusion

Firms often find it necessary to collaboratively develop new products and deliver them to new markets. In a survey of alliances, Accenture found that 6%–15% of the market value of a typical firm comes from its alliances, and the importance of collaborations is expected to grow (Kalmbach and Roussel 1999). We present evidence that cross-

function alliances are commonly perceived to underperform relative to same-function alliances when one or more partner shirks, all else equal. However, moving beyond perceptions, we show both theoretically and experimentally that the strategic investment behavior of partners in a same-function alliance and those in a cross-function alliance differs substantially. Our analysis sheds light on four important issues.

(1) *Why are there differences in the perceived performance of same-function and cross-function alliances?* The prevailing view of managers is that partners in cross-function alliances are more dependent on each other, and consequently, such alliances are more affected by shirking than same-function alliances. Furthermore, we find such beliefs about the performance of cross-function alliances can be adequately captured by a multiplicative function that maps resource input into alliance output, whereas the performance for same-function alliances can be adequately captured by an additive function. This implies that the value of the resources contributed by a firm in a cross-function alliance is highly contingent on the input supplied by the other partnering firms. Thus, if one partner shirks and does not put in the appropriate level of input, the value of other partners' input is greatly compromised. In contrast, the inputs for a same-function alliance are seen to be compensatory, and thus the value of one partner's input is independent of the level of inputs from other partners. As a result, the perceived likely performance of a cross-function alliance where one or more partners shirk had a lower mean than that of an equivalent same-function alliance. Furthermore, we observed greater variance in the perceived performance of cross-function alliances compared to that of same-function alliances conditional on a fixed set of inputs from partnering firms. This finding leads to the next issue.

(2) *Will cross-function alliances suffer from acute underinvestment problems?* Our theoretical analysis of the strategic behavior of firms suggests that in one equilibrium partners in cross-function alliances can invest nothing in their alliances. Thus, we offer a game-theoretic rationale for the common apprehension about cross-function alliances. But there is also a Pareto-superior equilibrium where partners in cross-function alliances will invest more than their counterparts in same-function alliances. Interestingly, Rokkan et al. (2003) show that partners in a vulnerable position might develop stronger bonds and demonstrate a greater sense of solidarity. In addition, we show that the collective investment of a cross-function alliance is not affected by the number of partnering firms. This is in contrast to our finding for same-function alliances where the collective investment decreases as the number of partnering firms increases.

(3) *What is the descriptive validity of the theoretical analysis of same-function and cross-function alliances?*

When we tested our model predictions we found that, on average, partners in cross-function alliances invested more than partners in same-function alliances, and their collective investment did not decrease as the number of partnering firms increased. Thus, the observed behavior is, in general, consistent with Propositions 1 and 2, although we also found considerable variation in behavior within partners and across partners. Our experimental findings differ from prior work where a team's joint effort was dependent on the lowest effort contributed by an individual in the team. In these prior studies, there was no competition between teams. This suggests that the presence of competition facilitated the shift toward the Pareto-superior equilibrium in our experiments.

(4) *How does opportunity for learning from an alliance affect the investment behavior of partnering firms?* Our analysis shows that opportunities for learning increase investment in the focal alliance but they do not change our original finding that partners in cross-function alliances invest more in their joint endeavor than those in same-function alliances. However, opportunities for learning may soften investments in the subsequent competition outside the scope of the alliance. In the presence of learning opportunities, any increase in interalliance competition dampens investments in the focal alliance but increases investment in the competition outside the scope of the alliance.

6.1. Direction for Future Research

Future research can broaden the sample of managers and consider relaxing some of our model assumptions to answer other questions about interfirm collaborations. For example, what is the best governance structure for cross-function alliances, where "best" is defined in terms of fostering efficient use of resources? Should the firms use a quasi-hierarchical structure (e.g., a joint venture) or a quasi-market structure (e.g., some sort of contractual agreement)? Some insights into this question can be found in Colombo (2003), Das and Teng (2001), and Li et al. (2009). Next, is there an incentive scheme that will moderate the effects of the two types of alliances on the size of collective investment? Hamman et al. (2007), for instance, show that an appropriately designed incentive scheme can draw players out of a bad equilibrium, though the effect is temporary. Are managers explicitly aware of the interactive nature of the cross-function response function or is the effect more subtle and implicit? We leave these open questions to future research.

In our analysis, we used a multiplicative performance function to model a cross-function alliance, and also showed that managerial perception is directionally consistent with this formulation. Alternatively, one can let the joint performance of a

cross-function alliance be determined by the minimum input of a partnering firm in the alliance (see Van Huyck et al. 1990 for minimum effort games). Although prior research has studied the effect of "minimum production function" on the performance of a team, it remains to be explored how such a performance formulation affects competition between teams. Recall that our conceptualization of a cross-function alliance is based on the notion that partners in such alliances pool dissimilar resources, and it does not distinguish between overlapping capabilities and overlapping activities of alliance partners. Future research can study the practical implications of the subtle but important distinction between overlapping capabilities and overlapping activities.

In developing our model of interpartner learning, we considered a two-stage game where firms jointly develop a technology or product in the first stage and then compete outside the scope of the alliance in the second stage. Our formulation is different from the racing models considered in prior literature on alliances (Khanna 1998, Khanna et al. 1998). In Khanna (1998) and Khanna et al. (1998), partners in a learning alliance make private investments to learn from alliance partners. The alliance partners are not tied together by a common purpose, but are engaged in a race to learn from each other. In our formulation, the alliance partners are jointly developing a new technology and are making investments to jointly win this technology competition. Second, in their conceptualization, learning and application of knowledge could be concurrent. In our formulation, firms first learn from their partners and then apply it outside the scope of their alliance. Third, in their formulation, both the common and private benefits are related to learning. In our formulation the common benefit includes gross profits from the new technology, whereas the private benefits include learning and the gross profits from the competition outside the scope of the alliance. Fourth, our analysis draws on the conceptual distinction between same-function and cross-function alliances based on the nature of inputs of partnering firms. Finally, whereas their analysis focuses on a dyad ($n = 2$), we propose a more flexible formulation that can consider $n > 2$ partners and $N > 2$ competing alliances. Future research can consider extending these racing models to study the strategic effects of interpartner learning on a multi-stage collaboration.

Furthermore, learning in alliances is a very broad phenomenon that can affect many facets of each partnering firm (see Mowery et al. 1996, Inkpen 2000, Khanna et al. 1998, Khanna 1998). In this paper, we considered one specific formulation of interpartner learning to understand how interpartner learning affects the joint investment in an alliance and the subsequent competition outside the scope

of the alliance. Future research can build on our model to allow for strategic investments in organizational processes to curtail leakage of knowledge, and also build new models to analyze other facets of interpartner learning. We tested some of our model predictions in a controlled laboratory setting. However, there are other avenues to corroborate the model predictions. Cross-sectional survey research (e.g., Rindfleisch and Moorman 2001) and longitudinal case studies (e.g., Koza and Lewin 1999) are two such methods, although it might be hard to precisely measure the actual resource allocation of each partner in a field setting.

7. Electronic Companion

An electronic companion to this paper is available as part of the online version that can be found at <http://mansci.journal.informs.org/>.

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Appendix

We first establish Lemmas 1 and 2, and then use them to prove Propositions 1 and 2.

LEMMA 1. *In the Pareto-superior equilibrium, the joint investment in cross-function alliance i is given by $X_i = (N - 1)V/N^2$.*

PROOF. The joint investment of cross-function alliance i is

$$X_i = \sum_{j=1}^n x_{ij}, \quad (7)$$

where $i \in \{1, 2, \dots, N\}$, $j \in \{1, 2, 3, \dots, n\}$. From (5), we know that the probability of alliance i winning the interalliance competition is given by

$$\Pr(i) = \frac{U(i)}{\sum_{k=1}^N U(k)}, \quad (8)$$

where $U(i) = \beta_2 \prod_{j=1}^n x_{ij}$. Hence, we have

$$\Pr(i) = \frac{\beta_2 \prod_{j=1}^n x_{ij}}{\sum_{k=1}^N (\beta_2 \prod_{j=1}^n x_{kj})} = \frac{\prod_{j=1}^n x_{ij}}{\sum_{k=1}^N \prod_{j=1}^n x_{kj}}. \quad (9)$$

From (6), we know that the payoff partner 1 in alliance i earns on investing x_{i1} is

$$\pi_{i1} = -x_{i1} + \Pr(i) \cdot \frac{V}{n}. \quad (10)$$

If $U(i) = 0 \forall i$, then no alliance develops the products and $\pi_{i1} = 0$.¹¹ We differentiate π_{i1} with respect to x_{i1} , set it to

¹¹ Note that each partner investing nothing is a symmetric pure-strategy equilibrium for cross-function alliances. In this equilibrium, alliance partners earn nothing. Note that this gives a lower payoff than the payoff from the symmetric pure-strategy equilibrium identified in Lemma 1. Thus, the equilibrium presented in Lemma 1 is Pareto superior. Our analysis focuses on the Pareto-superior equilibrium and provides support for it in the experimental investigation.

zero ($\partial \pi_{i1} / \partial x_{i1} = 0$), and solve for x_{i1} . After noting that the players are symmetric and simplifying the expression further, we get

$$x_{i1} = \frac{(N - 1)V}{nN^2}. \quad (11)$$

Moreover, there is an interior maximum for x_{i1} , because the payoff π_{i1} is concave in x_{i1} . That is,

$$\frac{\partial^2 \pi_{i1}}{\partial x_{i1}^2} < 0. \quad (12)$$

By adding the investments of all partners in cross-function alliance i (11), we obtain the joint investment

$$X_i = \frac{(N - 1)V}{N^2} \quad \square$$

LEMMA 2. *In the symmetric Nash equilibrium, the joint investment in same-function alliance i is given by $X_i = ((N - 1)V)/(nN^2)$.*

PROOF. The proof follows the same general logic used to establish Lemma 1. Let the utility of a product developed by a same-function alliance i be

$$U(i) = \beta_1 \sum_{j=1}^{n_i} x_{ij}. \quad (13)$$

The payoff partner 1 in alliance i earns on investing x_{i1} is as in (5):

$$\pi_{i1} = -x_{i1} + \Pr(i) \cdot \frac{V}{n}, \quad (14)$$

where $\Pr(i)$ is as given (4). If $U(i) = 0 \forall i$, then no alliance successfully develops the products and $\pi_{i1} = 0$. However, $U(i) = 0 \forall i$ is not an equilibrium because any player can invest $x_{ij} = \varepsilon > 0$ and win the competition to get $V/n > \varepsilon$.

We replace $U(i)$ with $x_{i1} + \sum_{j=2}^{n_i} x_{ij}$, differentiate π_{i1} with respect to x_{i1} , equate it to zero, and solve for x_{i1} . Later, by summing the investments of all the partners in same-function i we obtain X_i .

$$\frac{\partial \pi_{i1}}{\partial x_{i1}} = 0. \quad (15)$$

$$\begin{aligned} & -1 - \frac{V(x_{i1} + \sum_{j=2}^{n_i} x_{ij})}{n(\sum_{k=2}^N X_2 + x_{i1} + \sum_{j=2}^{n_i} x_{ij})^2} \\ & + \frac{V}{n(\sum_{k=2}^N X_2 + x_{i1} + \sum_{j=2}^{n_i} x_{ij})} = 0 \end{aligned} \quad (16)$$

Noting that the players are symmetric, we obtain

$$x_{ij} = \frac{(N - 1)V}{n^2 N^2}. \quad (17)$$

To establish that we have an interior maximum for x_{i1} , we show that the payoff π_{i1} is concave in x_{i1} :

$$\frac{\partial^2 \pi_{i1}}{\partial x_{i1}^2} = -\frac{2V \sum_{k=2}^N X_i}{n(\sum_{k=1}^N X_i)^3} < 0. \quad (18)$$

Using (17) we find that the sum of the investments of all partners in same-function alliance i is

$$X_i = \frac{(N - 1)V}{nN^2}. \quad \square$$

PROOF OF PROPOSITION 1. Denote the difference in the joint investment between cross-function and same-function alliance by Δ . Using Lemmas 1 and 2, we find that

$$\Delta = \frac{(N-1)V}{N^2} - \frac{(N-1)V}{nN^2} > 0. \quad \square$$

PROOF OF PROPOSITION 2. From Lemma 1, it immediately follows that in the case of cross-function alliance $\partial X_i / \partial n_i = 0$. Then, from Lemma 2, we can see that $\partial X_i / \partial n_i = -(N-1)V / (n^2 N^2) < 0$. This completes the proof. $\square$

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